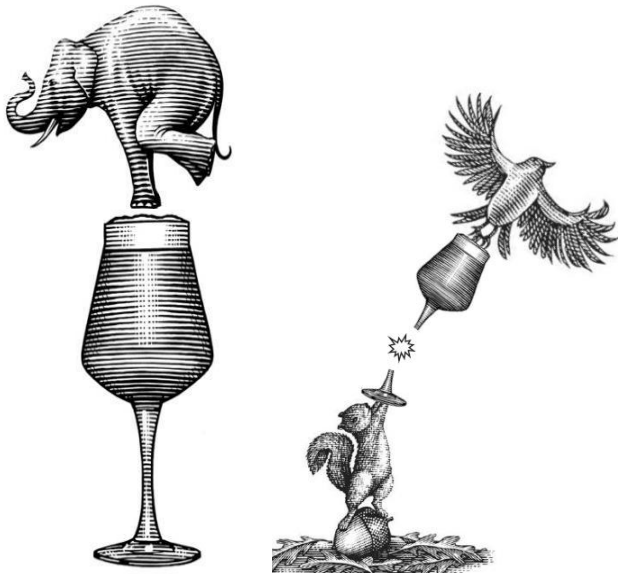


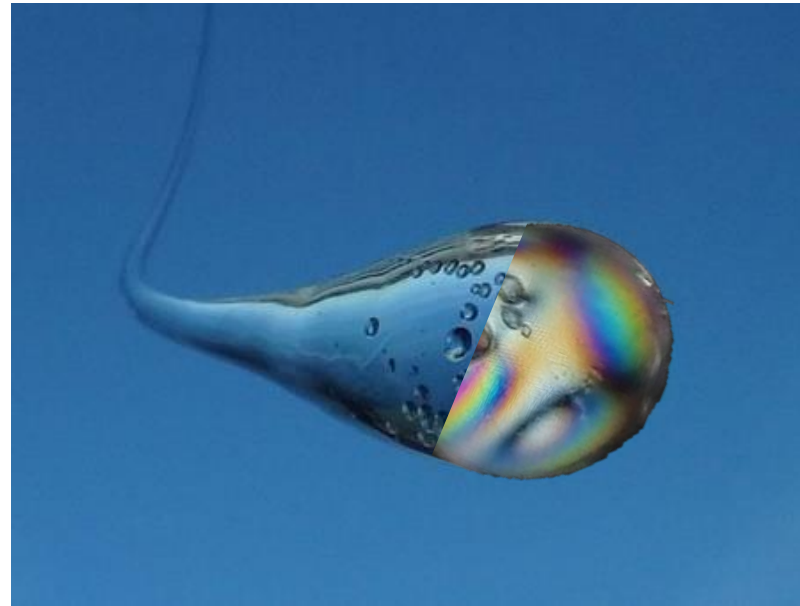
GLASS PERFORMANCE DAYS 2025

Novel tempered flat glass and its potential

Motivation

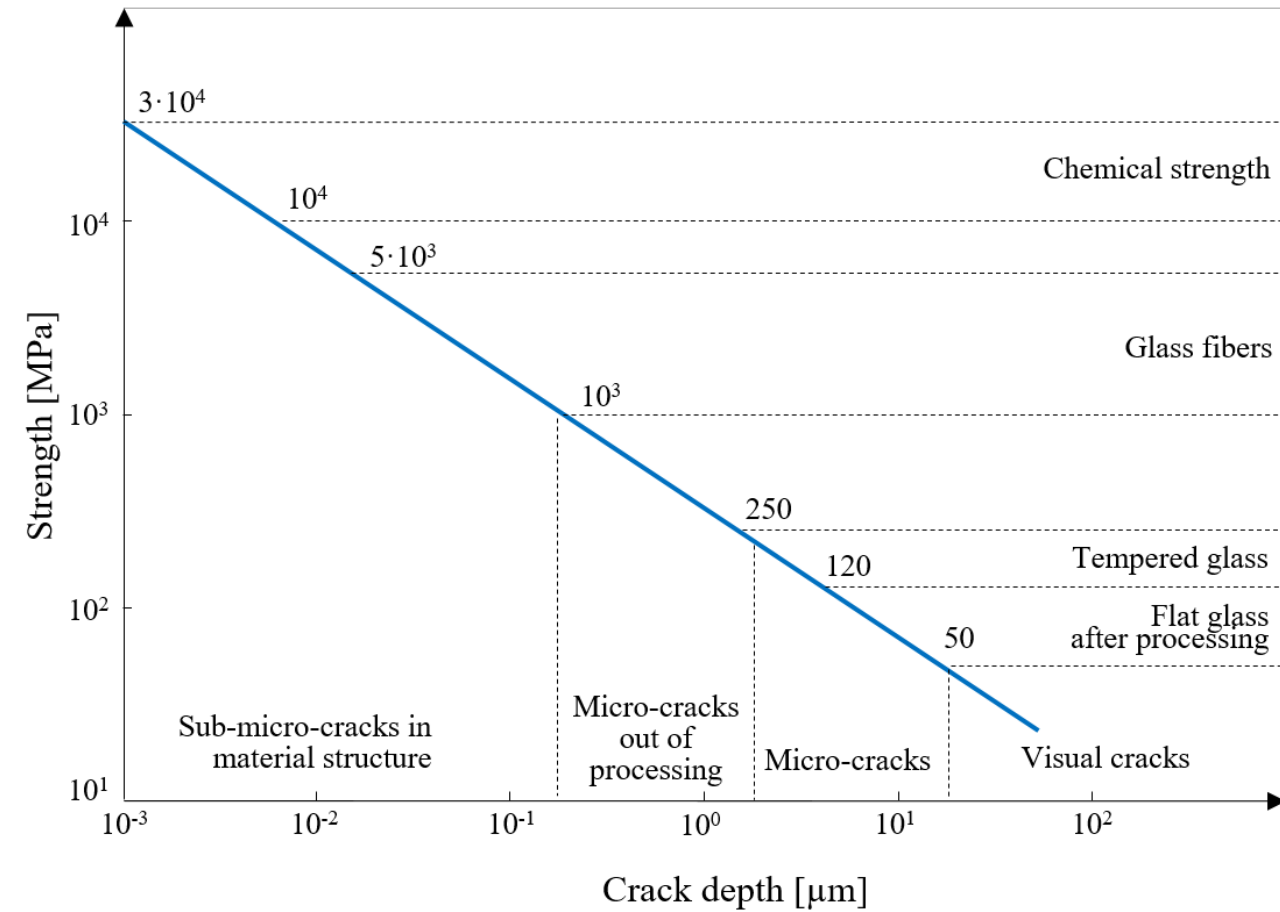


Source: Images from Steven Noble



Source: <https://eu.metrowestdailynews.com>

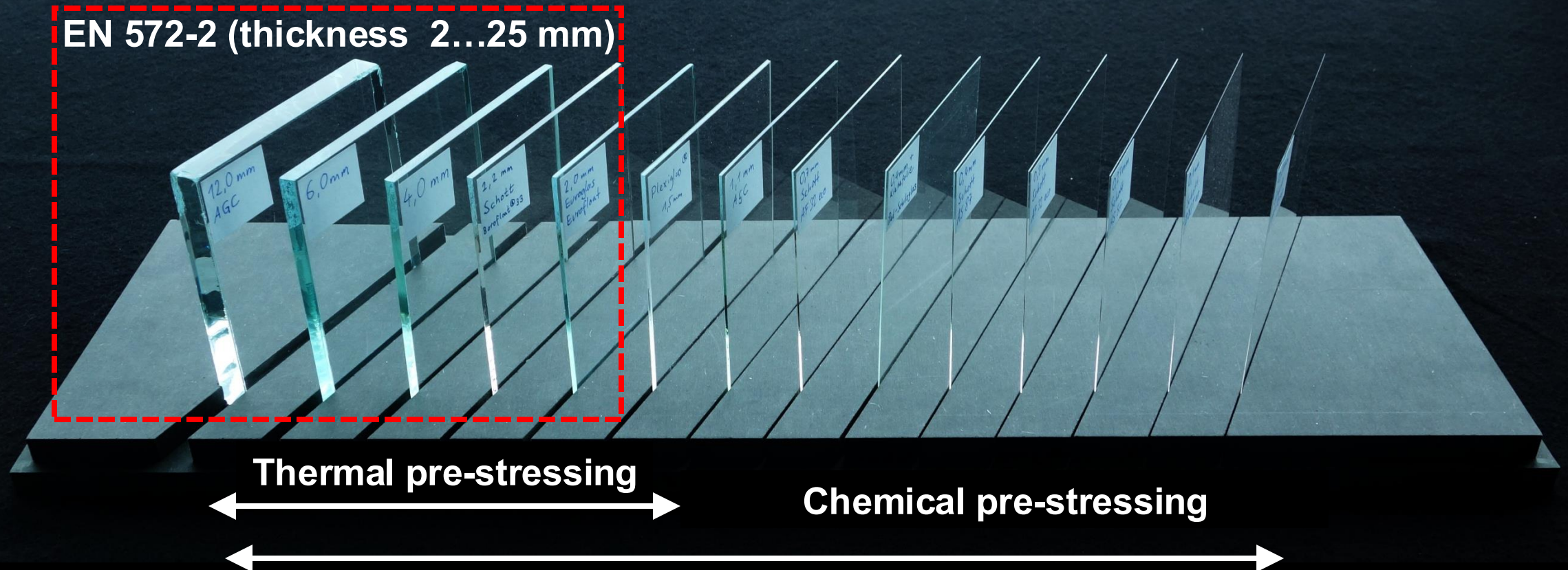
Motivation



Source: in accordance to PETZOLD, A., et al. (1990) Der Baustoff Glas: Grundlagen, Eigenschaften, Erzeugnisse, Glasbauelemente, Anwendungen.

Motivation

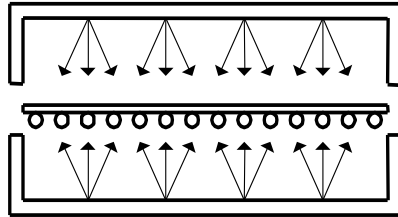
?? Is pre-stressing possible ??



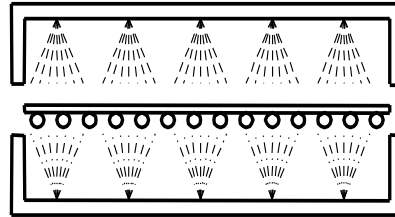
Pre-stressing methods

Thermal pre-stressing (tempering)

heating



cooling

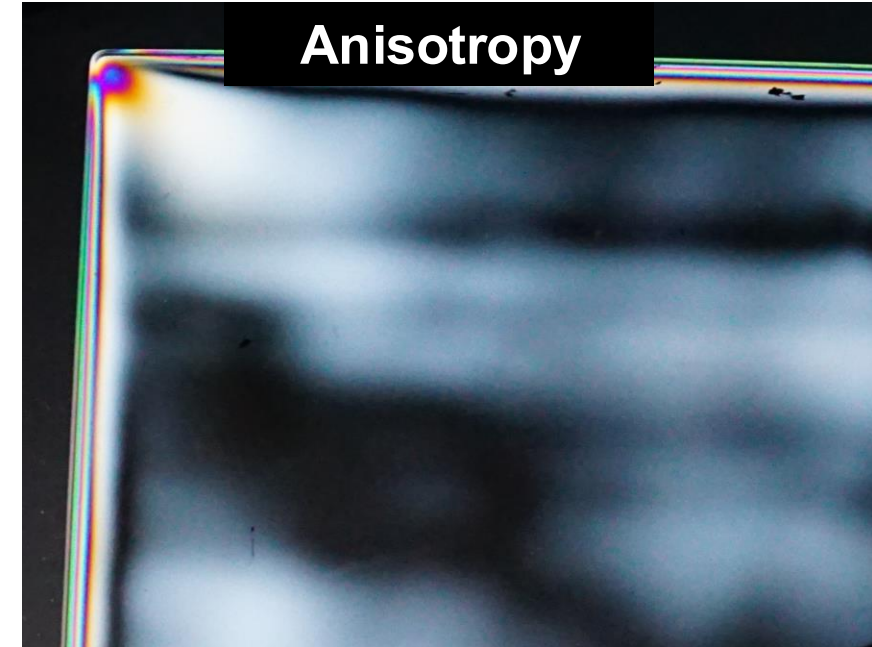


Source: Glaston

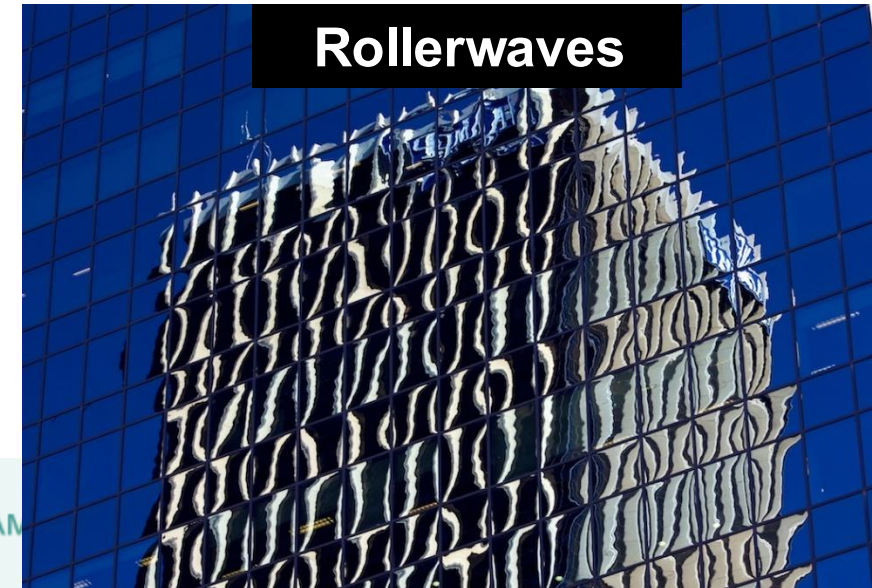
GLASS TEMPERATURE

625°C

Anisotropy

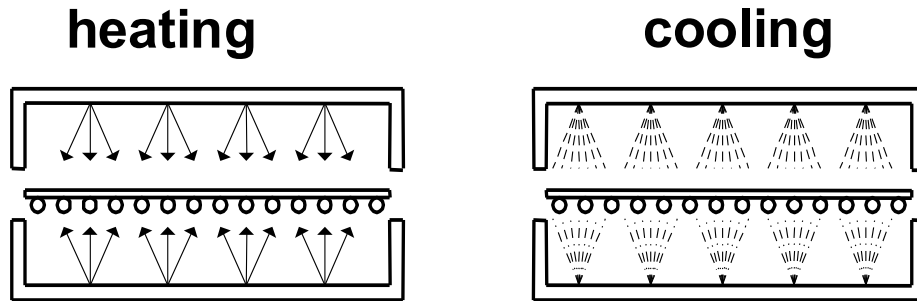


Rollerwaves

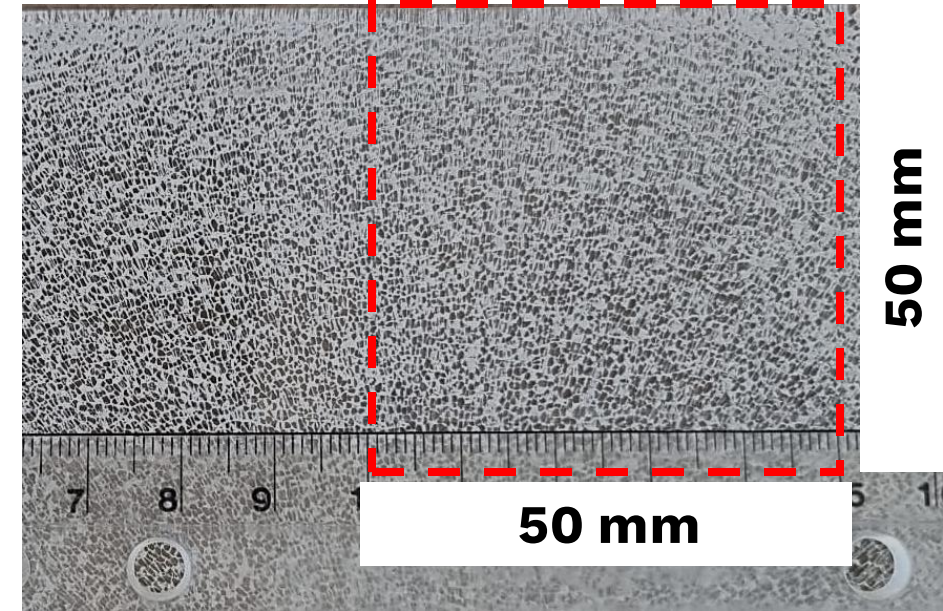


Pre-stressing methods

Thermal pre-stressing (tempering) – limits



Thickness 1.5 ... 3 mm (minimum limit)

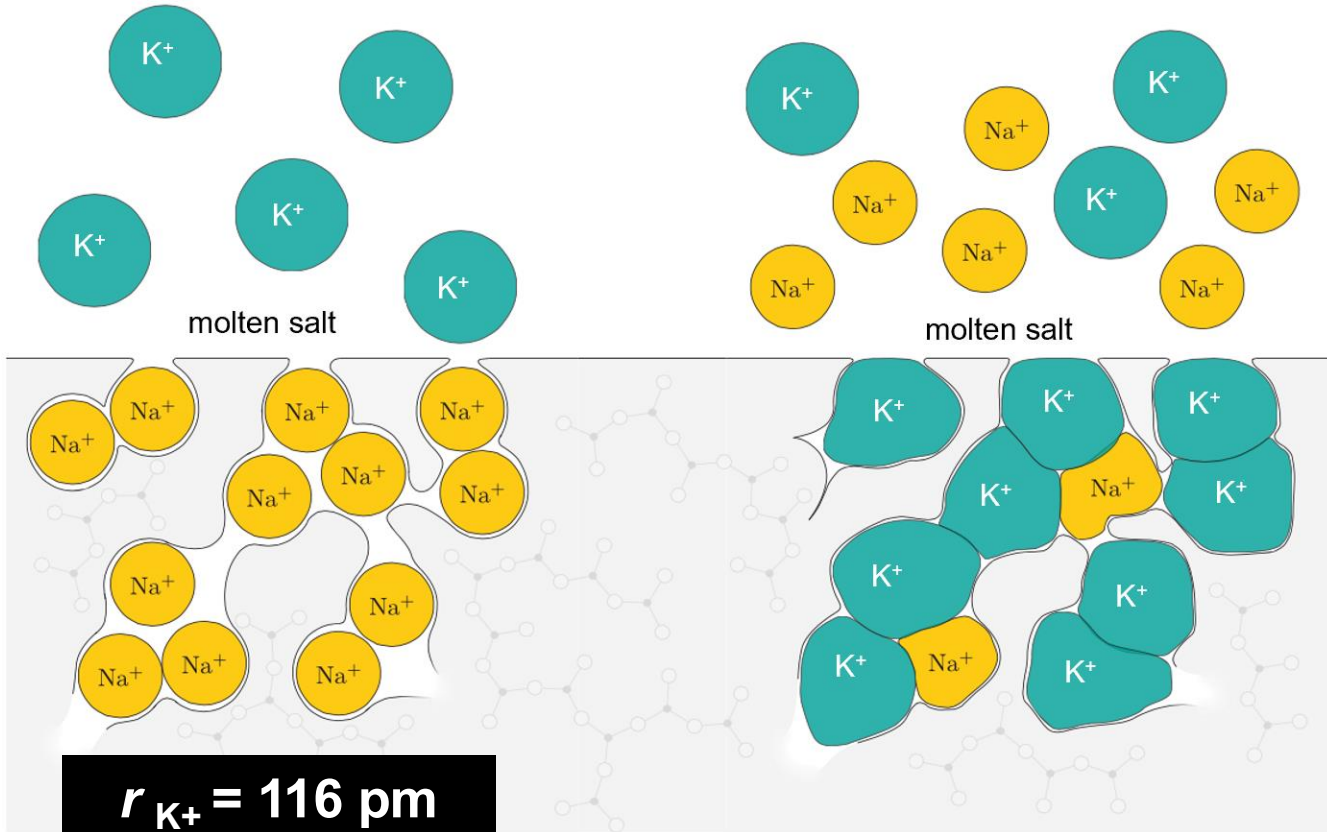


Please count!

Pre-stressing methods

Chemical pre-stressing (strengthening)

$$r_{K^+} = 152 \text{ pm} = 0.15 \text{ nm}$$



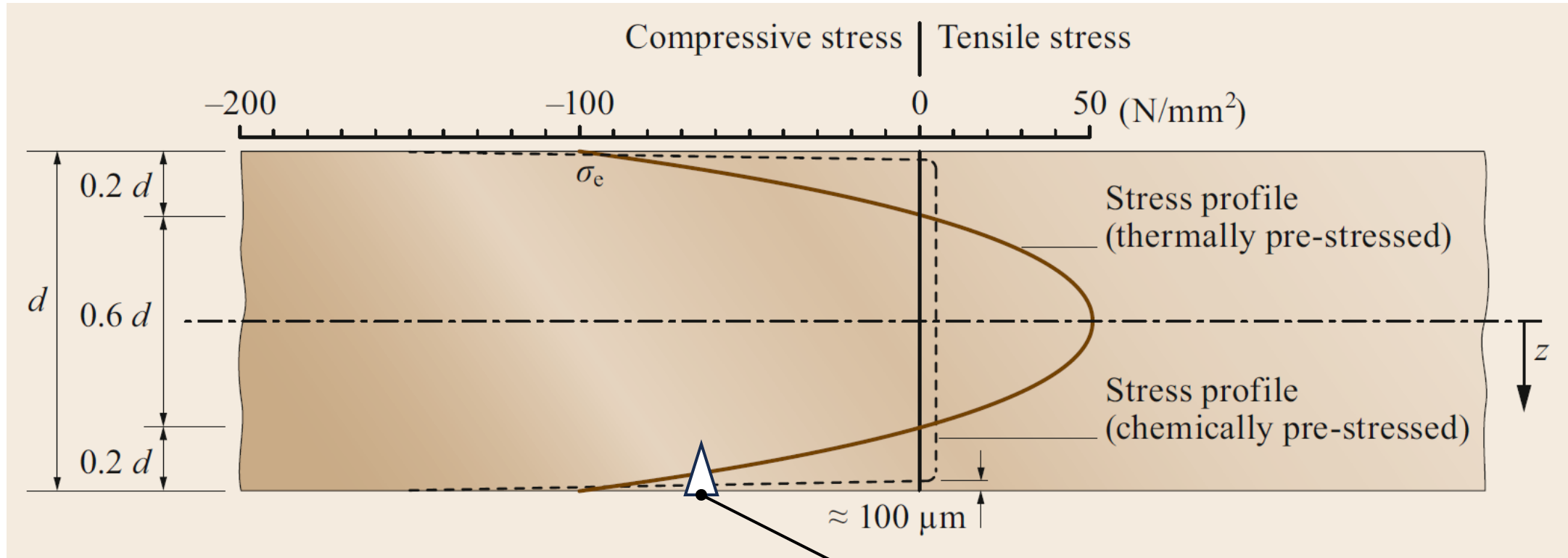
Time issue 4 .. 48 h



Source: Yachtglass GmbH & Co.

Pre-stressing methods

Stress profile



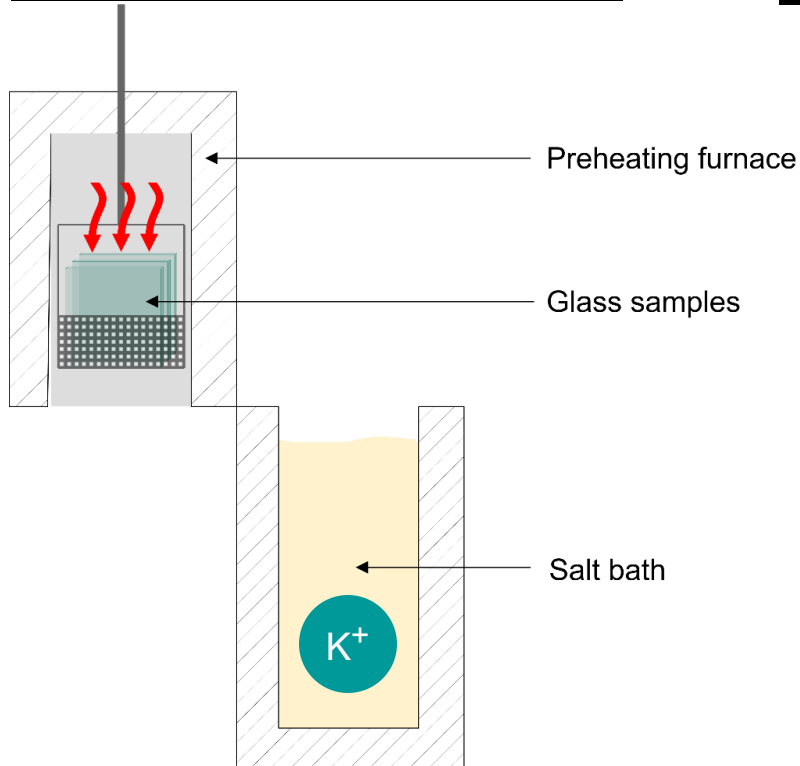
Source: Springer Handbook of Glass

Crack depth

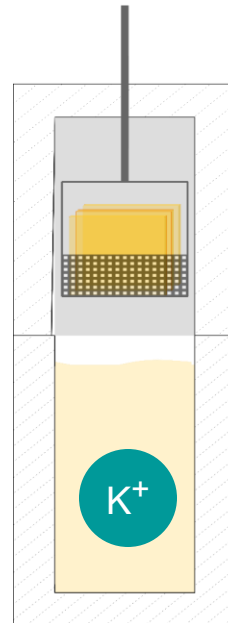
Pre-stressing methods

Thermal and chemical pre-stressing (hybrid approach)

1. step

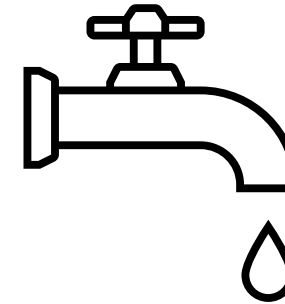


2. step



~ 30 Minuten

3. step



Pre-stressing methods

Thermal and chemical pre-stressing (hybrid approach)



Source: Revisal

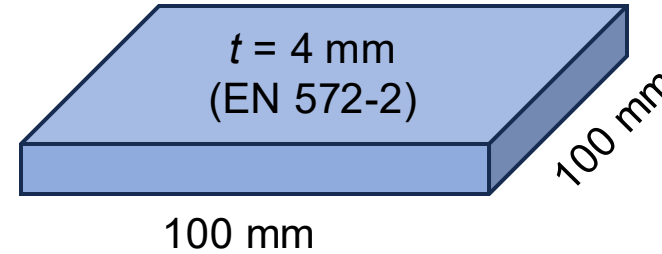
Samples and series overview



Glass
Competence
Center



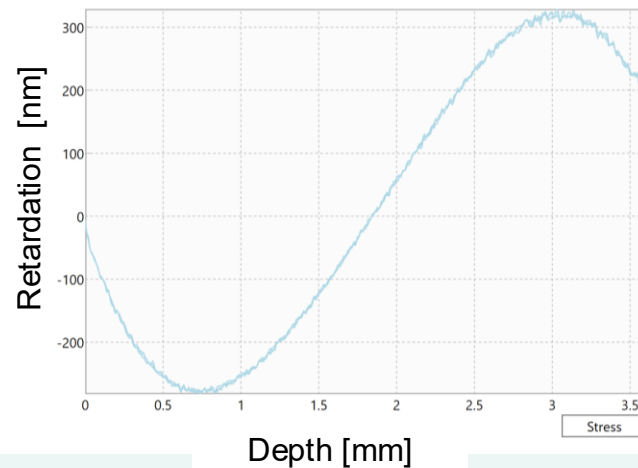
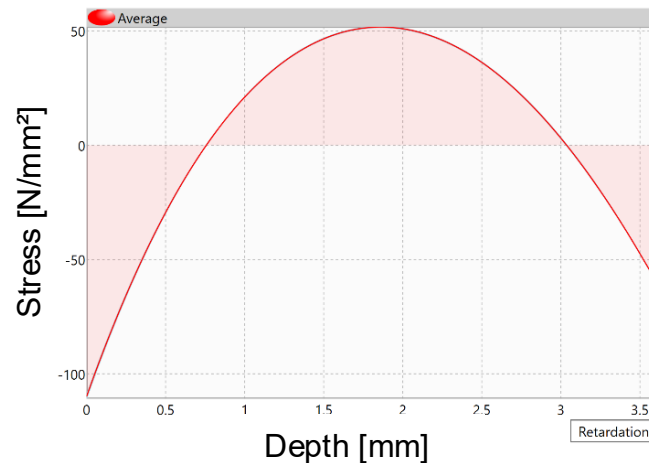
TECHNISCHE
UNIVERSITÄT
DARMSTADT



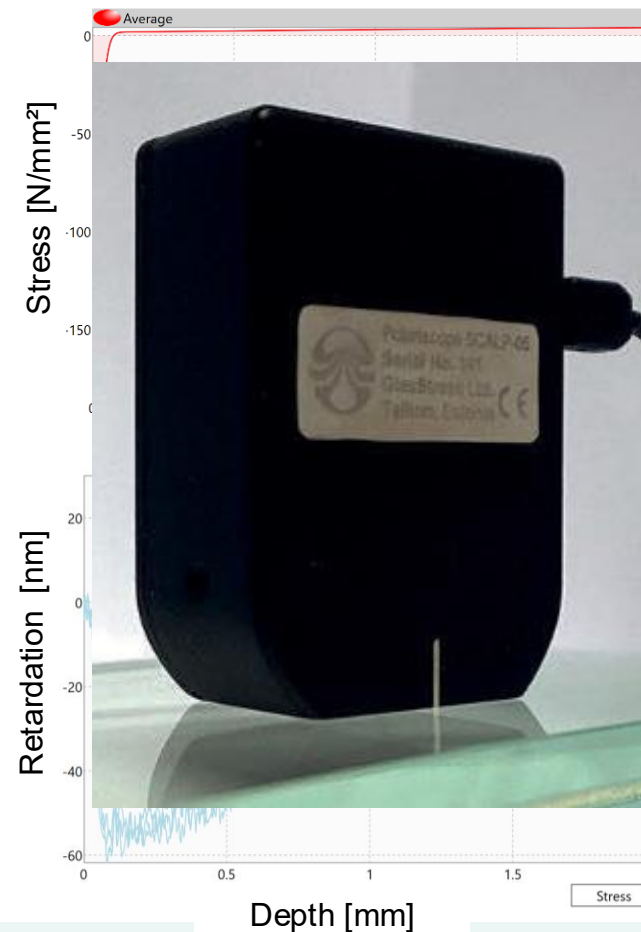
Glass type / product	Pre-stressing type	Standard	Series	Amount of samples in total	Investigation method			
					Anisotropy scanning	Residual stress measurement	Fracture pattern distribution	Strength (Coaxial double ring test)
Annealed soda-lime silicate glass (ANG)	-	EN 572-2	A	16	Yes (all)	No	No	Yes (10)
Heat strengthened glass (HSG)	Thermal pre-stressing	EN 1863-1	B	15	Yes (all)	Yes (3)	Yes (3)	Yes (10)
Thermally toughened glass (TTG)	Thermal pre-stressing	EN 12150-1	C	15	Yes (all)	Yes (3)	Yes (3)	Yes (10)
Chemically strengthened soda lime silicate glass (CSG)	Chemical pre-stressing	EN 12337-1	D	15	Yes (all)	Yes (3)	Yes (3)	Yes (10)
Novel toughened glass (NTG)	Thermal+ chemical pre-stressing	-	E	13	Yes (all)	Yes (3)	Yes (3)	Yes (10)

Investigation – Residual stress

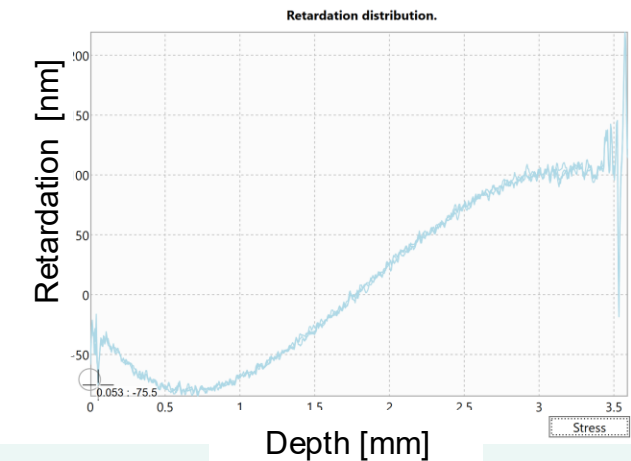
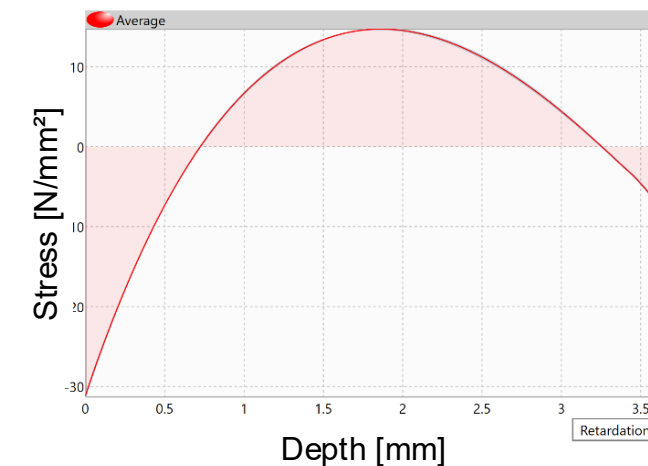
Thermally toughened glass (TTG)



Chemically strengthened silicate glass (CSG)



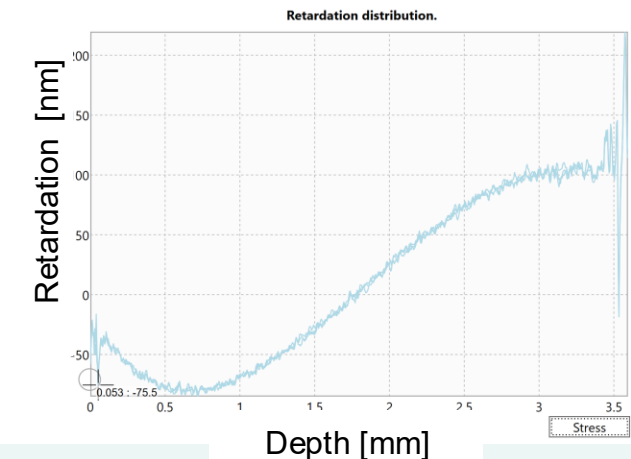
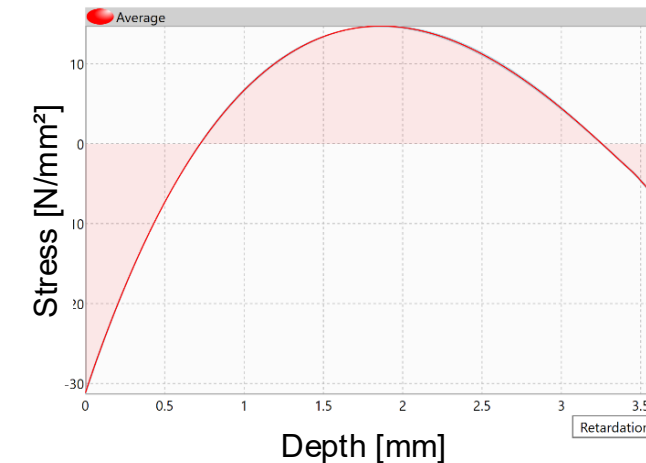
Novel toughened glass (NTG)



Residual stress

Glass type / product	Series	Mean value (standard deviation) per series
Annealed soda-lime silicate glass (ANG)	A	-2.8 (0)
Heat strengthened glass (HSG)	B	-92 (0.4)
Thermally toughened glass (TTG)	C	-108 (0.2)
Chemically strengthened soda-lime silicate glass (CSG)	D	-197 (27.4)
Novel toughened glass (NTG)	E	-32 (0.3)

Novel toughened glass (NTG)



Anisotropy & Fracture

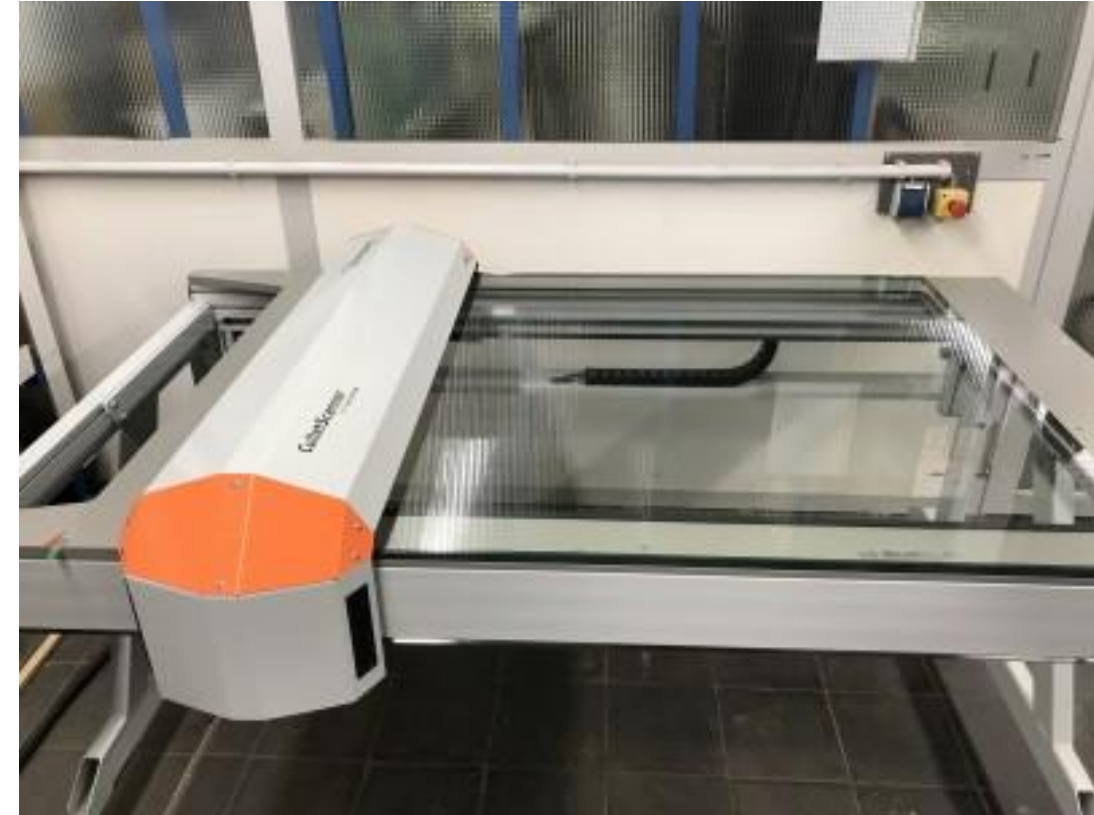
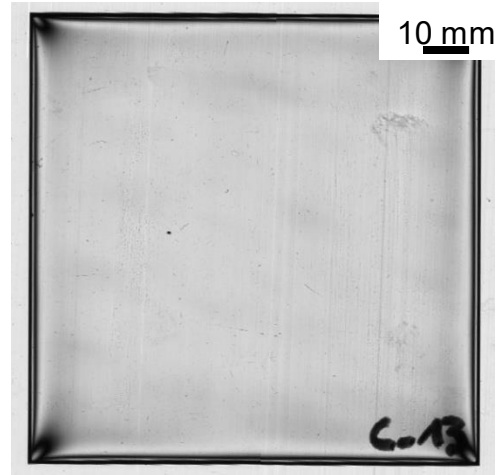
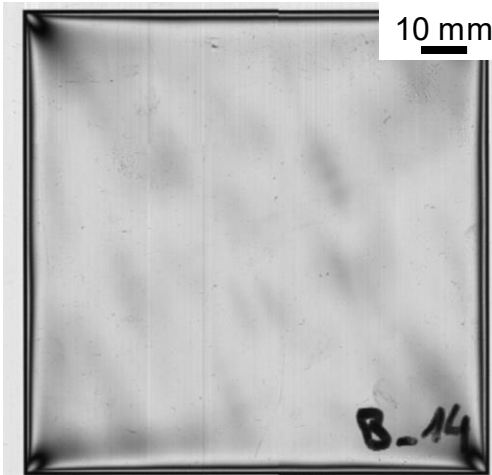
“Heat strengthened
glass (HSG)”

Thermally toughened
glass (TTG)

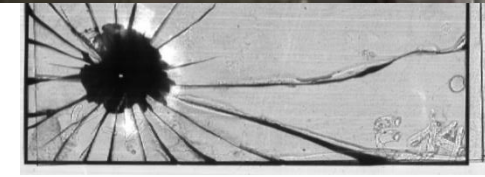
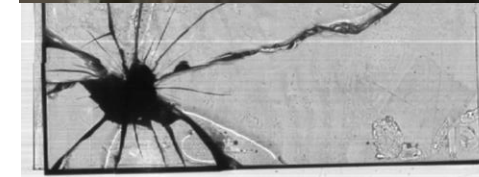
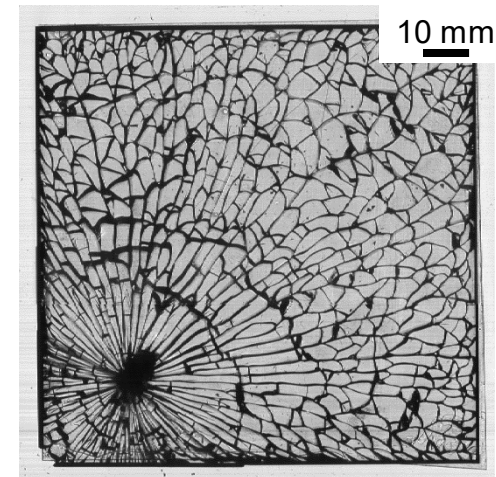
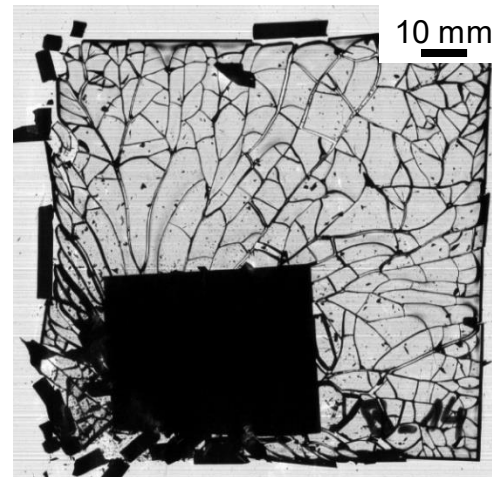
Chemically strengthened
silicate glass (CSG)

Novel toughened
glass (NTG)

Anisotropy



Fracture pattern



Strength evaluation

Douple ring test



- Adapted setup of EN 1288-5 (2000)
- Stress rate of 2 ± 0.4 MPa/s
- Loading ring 11 mm (radius)
- Support ring 30 mm (radius)

Strength evaluation

Annealed
soda-lime silicate
glass (ANG)

“Heat
strengthened glass
(HSG)”

Thermally
toughened
glass (TTG)

Chemically
strengthened
silicate glass
(CSG)

Novel toughened
glass
(NTG)

Fracture
pattern



Strength evaluation

Glass type	Series	Amount of valid/ total samples	Values				
			Min. [MPa]	Max. [MPa]	Expected value** [MPa]	Coefficient of variation** [-]	Characteristic strength * [MPa]
Soda-lime silicate glass (SLG)	A	8/10	60	170	140	0.26	49
Heat strengthened glass (HSG)	B	9/10	197	319	241	0.2	156
Thermally toughened glass (TTG)	C	9/10	186	328	252	0.2	163
Chemically strengthened soda lime silicate glass (CSG)	D	10/10	517	681	597	0.12	464
Novel toughened glass (NTG)	E	6/10	142	638	593	0.76	70

Ball trop test



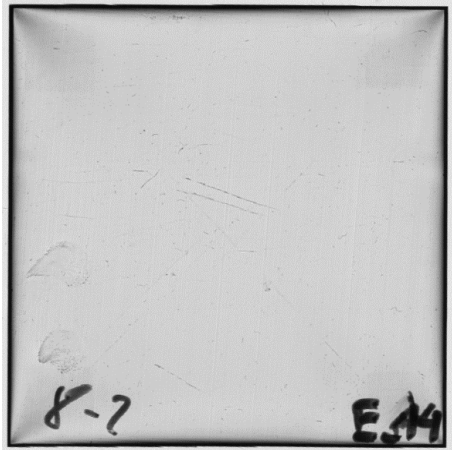
Thermally toughened
glass (TTG)
700 mm



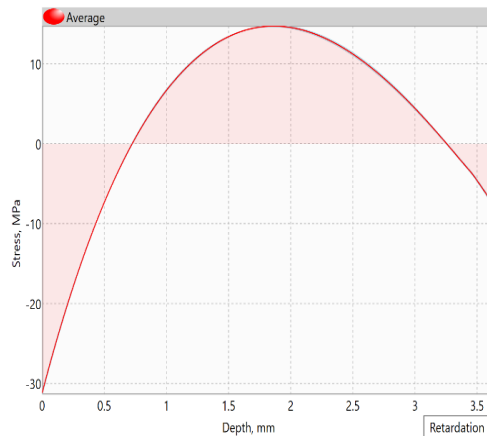
Novel toughened
glass (NTG)
min. 1300 mm

Conclusion – NTG

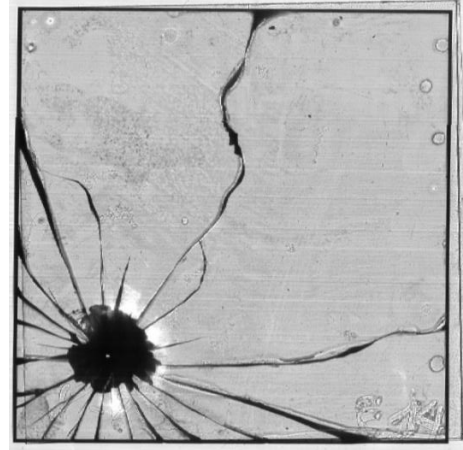
Less anisotropy
effects



Stress profile
measurement
is “hard”



Rough crack
pattern

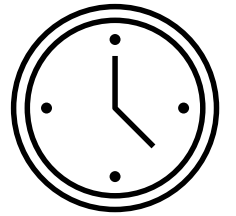


High strength
(like CSG)



593 N/mm² (“mean”),
but scattering

Fast tempering
process + “min.
thickness” 0.5 mm



~ 30 Minuten

better quality for
façade glazing

New method is
necessary

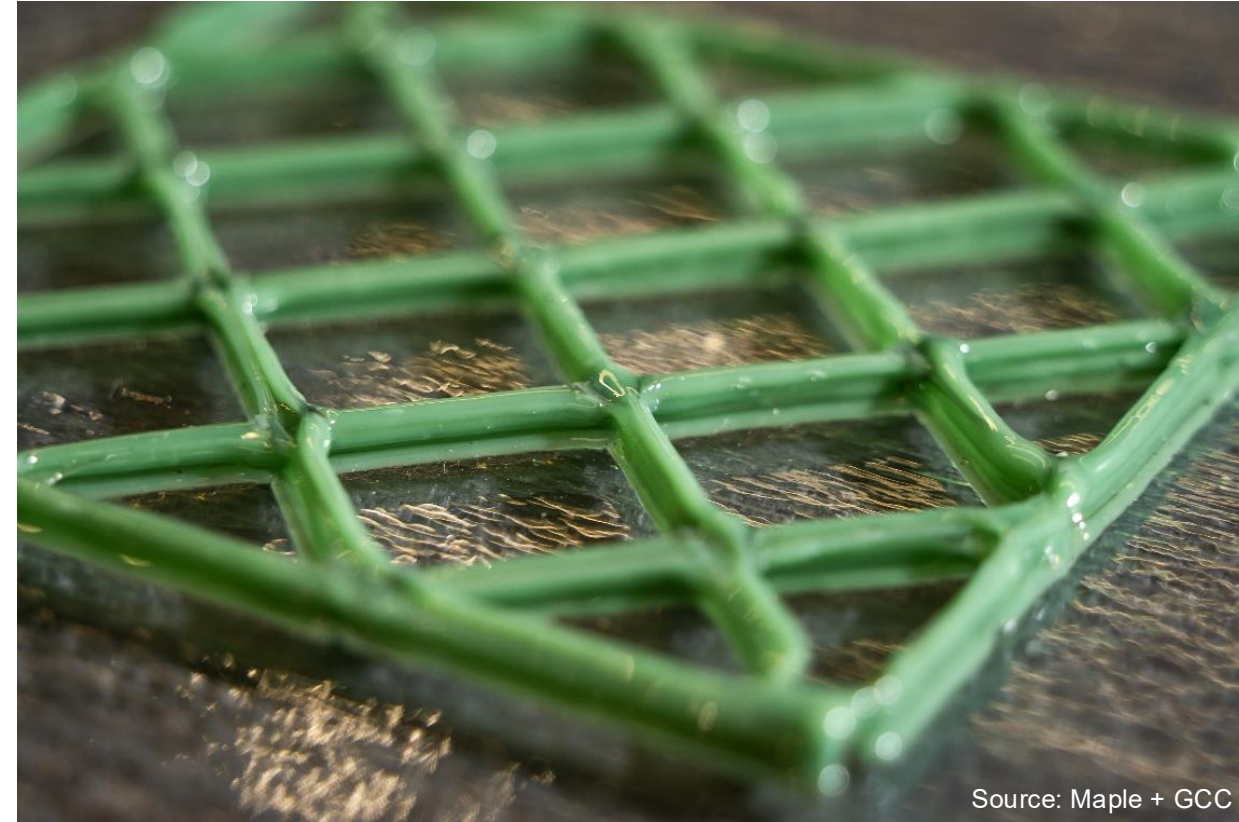
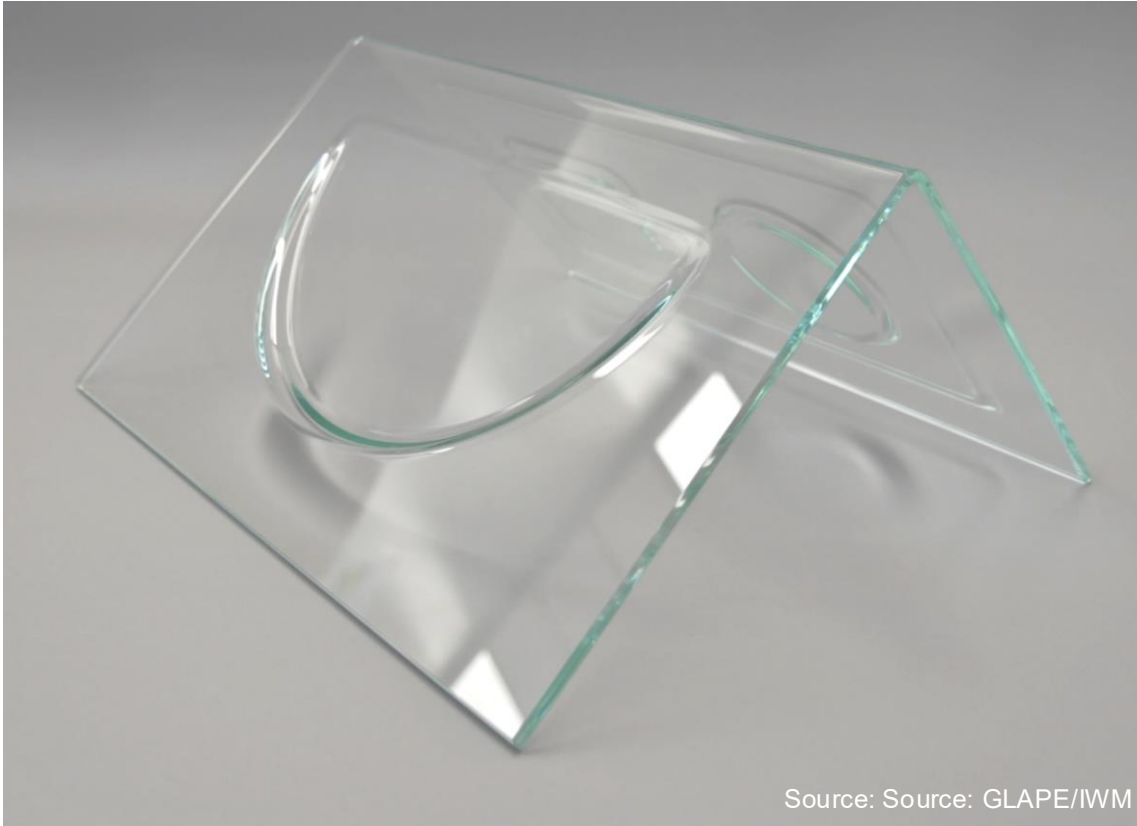
High load bearing
capacity
(post-fractured state
as LSG)

High performance
glass
(“Fire safety glass”)

Cheaper process
+thin glass
tempering

Outlook

Pre-stressing of complex structures



Pre-stressing of thin glass



**Thank you
for
your
attention**



Contact:

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seel@ismd.tu-darmstadt.de

